COMM ACADEMY 2014

MODERN INTERFERENCE (IX) ISSUES AND PUBLIC SAFETY COMMUNICATIONS

Andy Ruschak KK7TR

Agenda

- WWRIC
- R43
- Interference Implications for Public Safety
- Interference Implications for Cellular Carriers
- Frequency Coordination and Engineering Studies
- BDA generated Interference
- PIM (Passive Inter-Modulation) Interference
- Multipath Interference and P25 Digital Systems
- Other sources of Interference

WWRIC

- Western Washington Regional Interference Committee
  - Non-profit organization that promotes clean, efficient use of radio spectrum by establishing radio site engineering standards, problem resolution, FCC lobbying and interaction between radio system users.
- **Site Engineering Standards**
  - Publishes radio transmitter site engineering standards for "best practices" to prevent IX
  - Standard can be downloaded from: wwric.org/Resources.htm

wWRIC
Western Washington Regional Interference Committee
"Addressing RF Interference in the Pacific Northwest since 1955"
home
resources
meetings
newsletter
about us

www.wwric.org

WWRIC

- **Interference Reports**

  - Encourages reporting IX problems to the Group as well as to the FCC

  - Members can assist with locating and resolving IX problems, cooperatively within the wireless community and the FCC

- **Membership**

  - Open to wireless communications professionals from private sector, government agencies, amateur radio operators, wireless equipment manufacturer and consultants to the wireless industry.

- **Monthly Meetings**

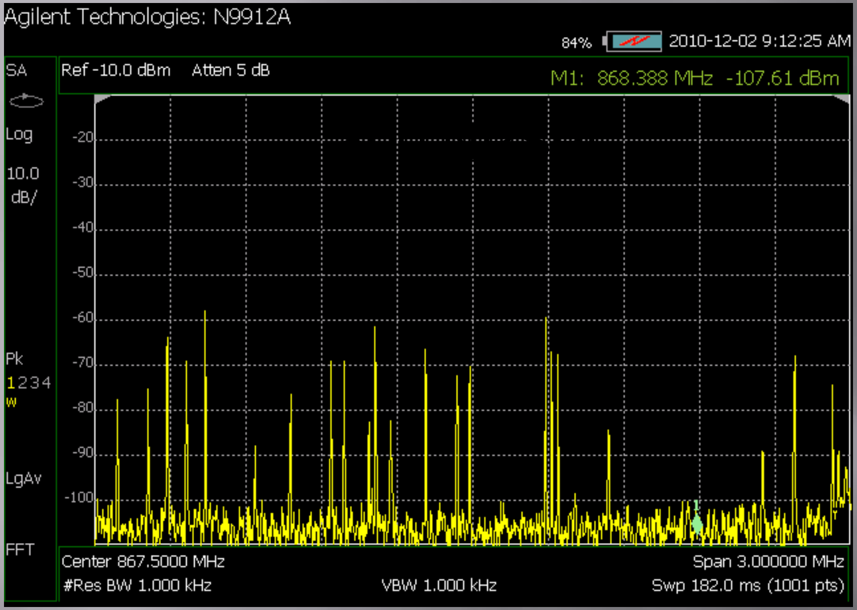
  - 9:30 AM on 2nd Tuesday of each month (except August), at the WSP District Office in Bellevue

  - Open to anyone interested in IX issues
  - provides an opportunity to help with IX resolution and prevention
  - provides a forum for learning and networking with others in the wireless community

General Interference Concepts

- Other radio services (ex. Part 90) in some ways suffer from greater interference potential than Part 97
- Greater levels of activity
- Activity directly adjacent above and below operational frequencies
- Examples include VHF, UHF, 800 MHz

Real-World Signal Activity

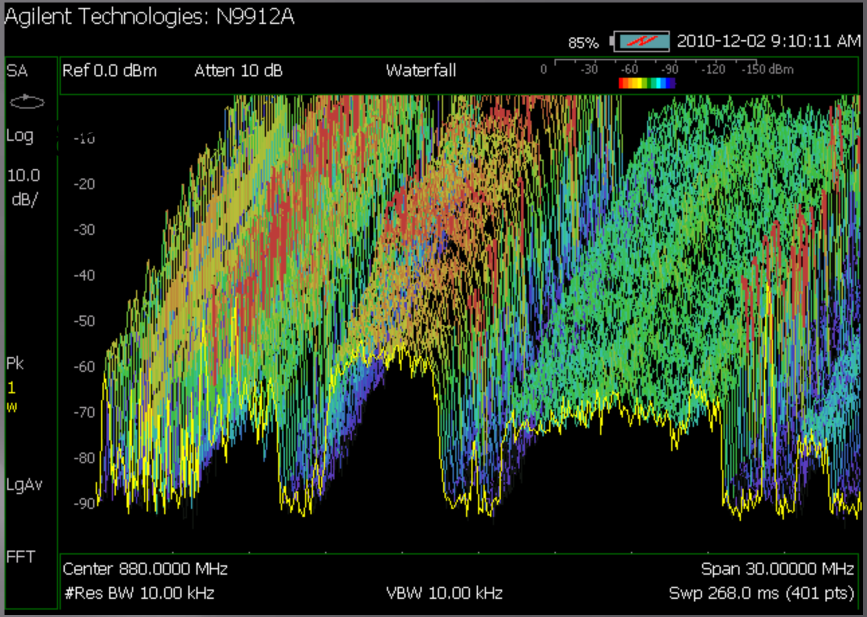

Agilent Technologies: N9912A

84% 2010-12-02 9:12:25 AM

SA
Ref -10.0 dBm Atten 5 dB
M1: 868.388 MHz -107.61 dBm

Log
10.0 dB/
Pk 1234 W
LgAv
FFT

Center 867.5000 MHz
Span 3.000000 MHz
#Res BW 1.000 kHz
VBW 1.000 kHz
Swp 182.0 ms (1001 pts)

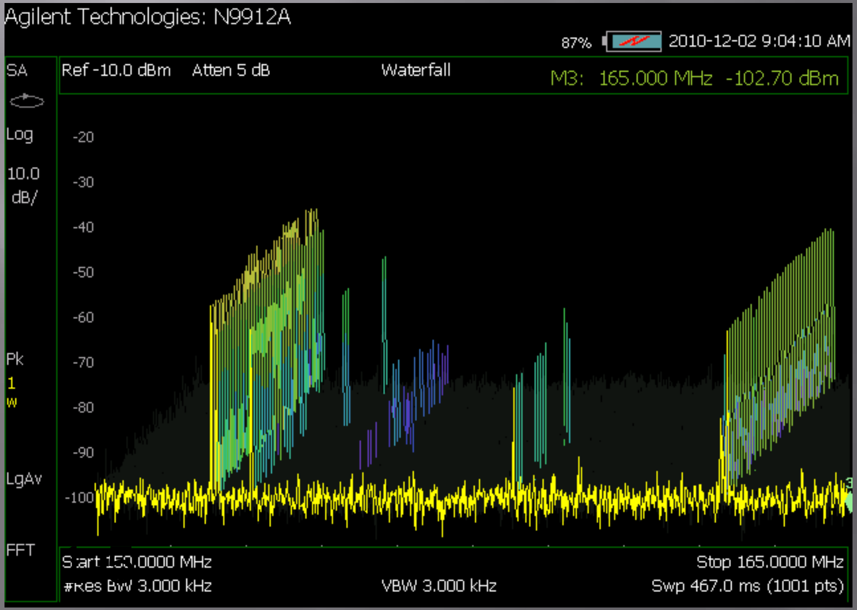

Agilent Technologies: N9912A

85% 2010-12-02 9:10:11 AM

SA
Ref 0.0 dBm Atten 10 dB Waterfall

Log
10.0 dB/
Pk 1 W
LgAv
FFT

Center 880.0000 MHz
Span 30.00000 MHz
#Res BW 10.00 kHz
VBW 10.00 kHz
Swp 268.0 ms (401 pts)

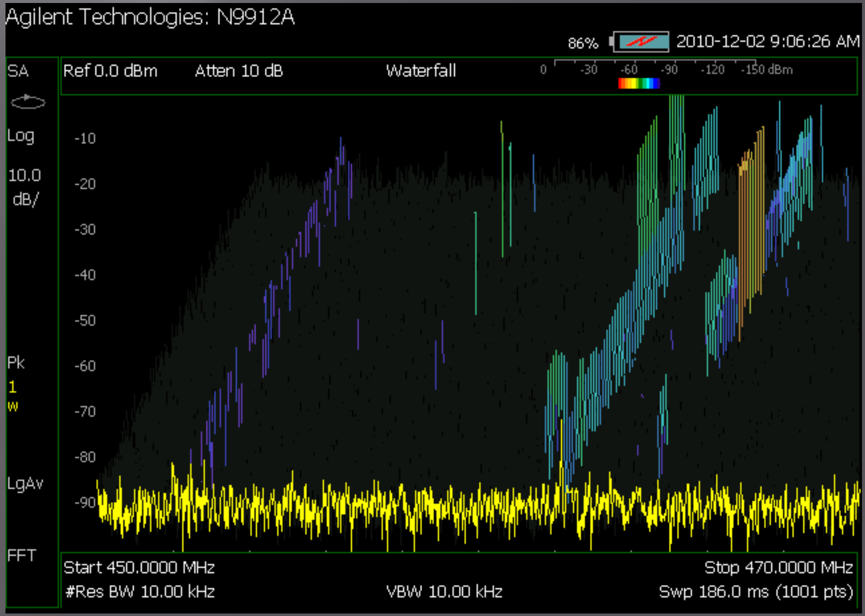

Agilent Technologies: N9912A

87% 2010-12-02 9:04:10 AM

SA
Ref -10.0 dBm Atten 5 dB Waterfall
M3: 165.000 MHz -102.70 dBm

Log
10.0 dB/
Pk 1 W
LgAv
FFT

Start 150.0000 MHz
Stop 165.0000 MHz
#Res BW 3.000 kHz
VBW 3.000 kHz
Swp 467.0 ms (1001 pts)


Agilent Technologies: N9912A

86% 2010-12-02 9:06:26 AM

SA
Ref 0.0 dBm Atten 10 dB Waterfall

Log
10.0 dB/
Pk 1 W
LgAv
FFT

Start 450.0000 MHz
Stop 470.0000 MHz
#Res BW 10.00 kHz
VBW 10.00 kHz
Swp 186.0 ms (1001 pts)

IX Implications for Public Safety

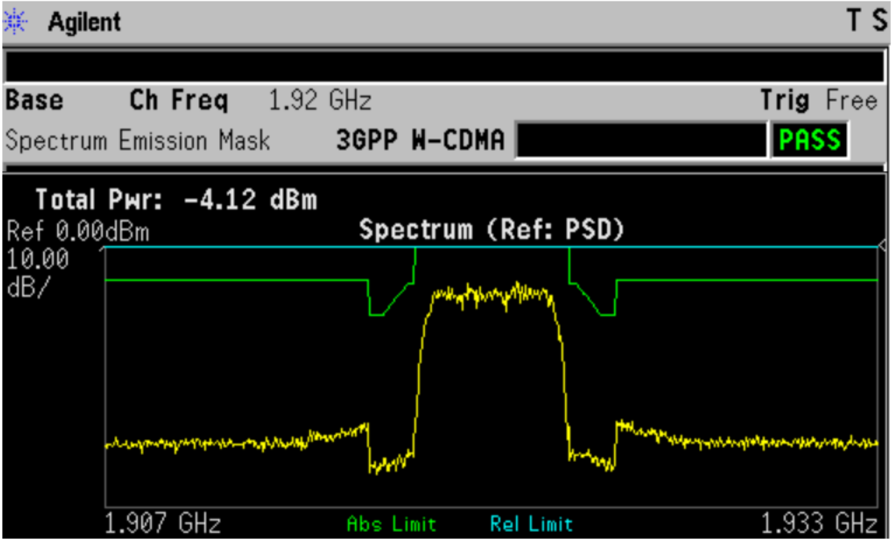
- Public Safety First Responder Communication is Mission Critical and Life Safety
    - Interruption of service has serious implications
- Can affect Voice and/or Data Communications
    - Paging
    - MDT (Mobile Data Terminals)
    - PTT ID
- Proper operation of trunked system operation
    - Control channel operation (ISW/OSW "handshake")
    - Common 800 MHz channels closely coordinated
    - Re-banding of 800 MHz spectrum was result of IX

IX Implications for Cellular Carriers

- Cellular spectrum blocks represent millions to *billions* of dollars of investment (700 MHz, 850 MHz, 1900 MHz, 2100 MHz)
- Each band has "blocks" assigned by market region, coordination on a nationwide scale the norm
- By design, carriers are extremely cognizant of IX
  - IX affects handset power and battery life
  - IX affects site capacity
  - IX affects data throughput speeds
- Poor performance and dropped calls affect revenue, subscriber churn and market position

IX Implications for Cellular Carriers

- Carriers are common “smoking gun” for IX – often incorrectly
- Carrier share spectrum on 700 & 800 MHz with Public Safety
- Some PS and Carriers are co-located in same facility & tower
- Modern cellular BTS infrastructure has ability to self-monitor and shut down if emission is out of specification


Agilent T S

Base Ch Freq 1.92 GHz Trig Free

Spectrum Emission Mask 3GPP W-CDMA PASS

Total Pwr: -4.12 dBm

Ref 0.00dBm

10.00 dB/

Spectrum (Ref: PSD)

Interference Implications

- Several sources of Interference to 800 MHz Public Safety
  - BDA (Bi-Directional Amplifier) Systems
  - Wireless Carriers
  - Passive Inter Modulation (PIM)

Region 43

- **National Public Safety Planning Advisory Committee (NPSPAC) Region 43 800 MHz Regional Review Committee**

  - Addresses allocation of public safety 800 MHz spectrum

  - FCC's sets national guidelines for 800 MHz use but allows regional planning committees to develop regional plans tailored to their particular communications needs

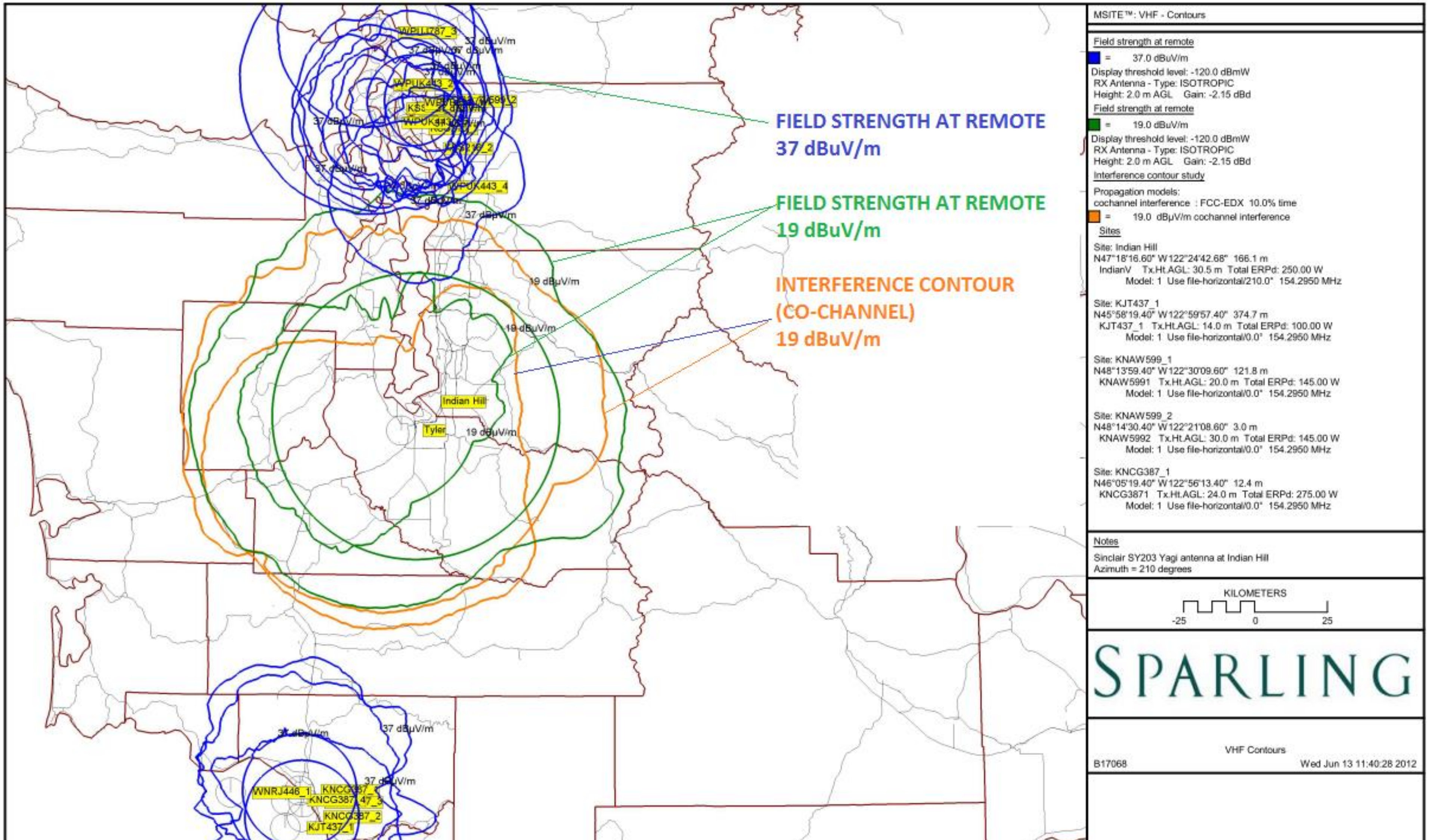
  - RPC's are "deputized" by the FCC to handle vetting and approval of licensing

  - Groups meets monthly to review new frequency requests

Frequency Coordination

- Heavily used under Part 90 for LMR and Government Radio
- Frequency Spectrum is very scarce, especially in metro regions
- Co-channel and Adjacent channels must be coordinated
- Required before FCC will issue license
- Must prove non-interference by engineering analysis
- Frequency Reuse is required, not an option
- Despite large pools of channels, they are rapidly exhausted
- Many large metropolitan cities surrounded by rural regions – rural regions also suffer from frequency depletion
- Canadian border regions

Co-Channel & Adj. Channel IX Study



FIELD STRENGTH AT REMOTE
37 dBuV/m

FIELD STRENGTH AT REMOTE
19 dBuV/m

INTERFERENCE CONTOUR
(CO-CHANNEL)
19 dBuV/m

MSITE™: VHF - Contours

Field strength at remote

🟦 = 37.0 dBuV/m

Display threshold level: -120.0 dBmW
RX Antenna - Type: ISOTROPIC
Height: 2.0 m AGL Gain: -2.15 dBd

Field strength at remote

🟩 = 19.0 dBuV/m

Display threshold level: -120.0 dBmW
RX Antenna - Type: ISOTROPIC
Height: 2.0 m AGL Gain: -2.15 dBd

Interference contour study

Propagation models:
cochannel interference : FCC-EDX 10.0% time

🟧 = 19.0 dBμV/m cochannel interference

Sites

Site: Indian Hill
N47°18'16.60" W122°24'42.68" 166.1 m
IndianV Tx.Ht.AGL: 30.5 m Total ERPd: 250.00 W
Model: 1 Use file-horizontal/210.0° 154.2950 MHz

Site: KJT437_1
N45°58'19.40" W122°59'57.40" 374.7 m
KJT437_1 Tx.Ht.AGL: 14.0 m Total ERPd: 100.00 W
Model: 1 Use file-horizontal/0.0° 154.2950 MHz

Site: KNAW599_1
N48°13'59.40" W122°30'09.60" 121.8 m
KNAW5991 Tx.Ht.AGL: 20.0 m Total ERPd: 145.00 W
Model: 1 Use file-horizontal/0.0° 154.2950 MHz

Site: KNAW599_2
N48°14'30.40" W122°21'08.60" 3.0 m
KNAW5992 Tx.Ht.AGL: 30.0 m Total ERPd: 145.00 W
Model: 1 Use file-horizontal/0.0° 154.2950 MHz

Site: KNCG387_1
N46°05'19.40" W122°56'13.40" 12.4 m
KNCG3871 Tx.Ht.AGL: 24.0 m Total ERPd: 275.00 W
Model: 1 Use file-horizontal/0.0° 154.2950 MHz

Notes

Sinclair SY203 Yagi antenna at Indian Hill
Azimuth = 210 degrees

SPARLING

VHF Contours

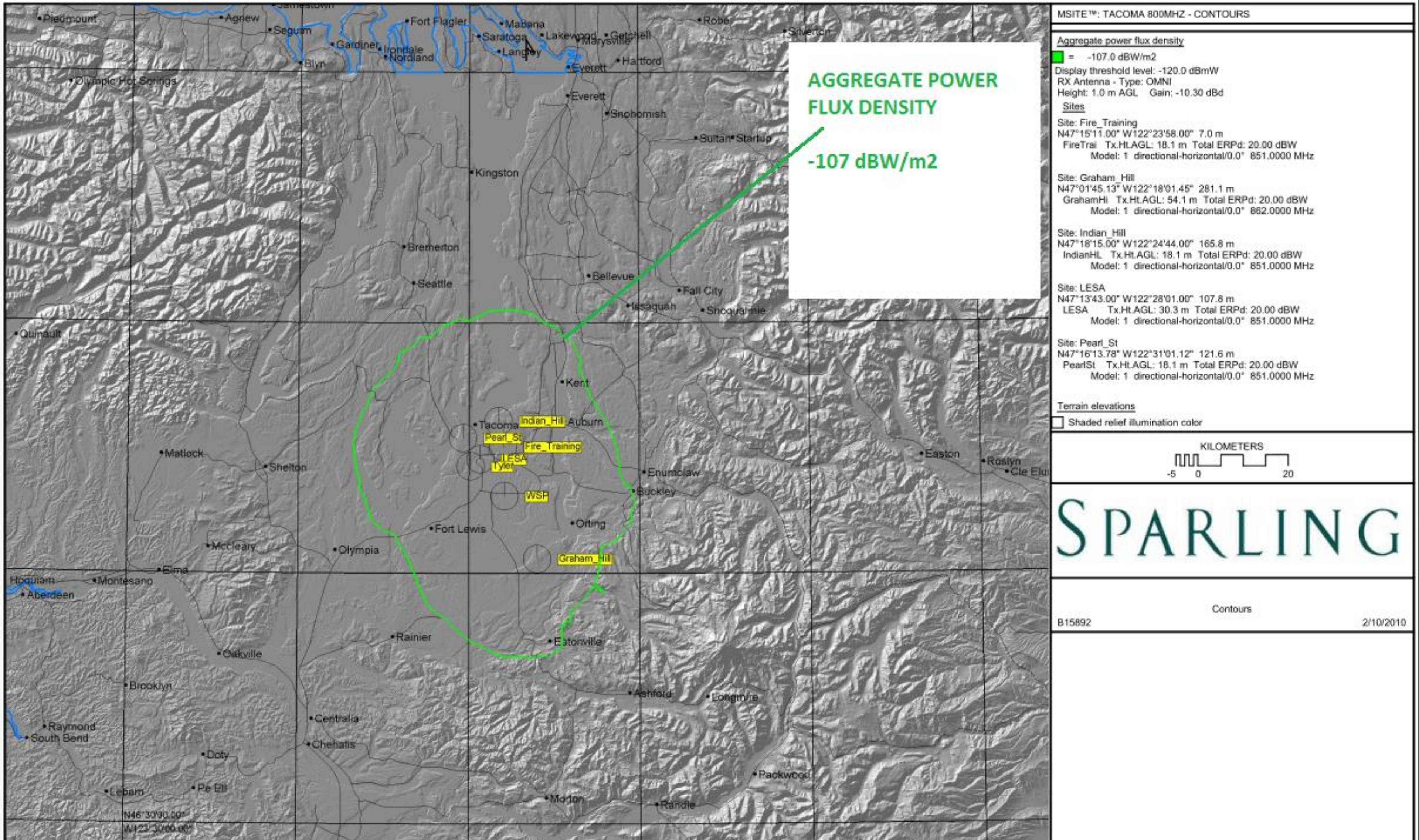
B17068

Wed Jun 13 11:40:28 2012

Power Flux Density

- Mandatory in border regions with Canada
- Engineering study demonstrating non-interference to Canadian operations.
- Show that signal strength < -148 dBW (VHF),< -146 dBW (UHF) or -107 dBW (800) received by Canadian stations.
- Engineering study must show worst case situation (i.e., location of the mobile units at the edge of service area).
- Can request exemption Mobiles operating < 5 watts but must accept operation on a secondary non-interference basis to current and future Canadian operations.

Power Flux Density



AGGREGATE POWER FLUX DENSITY

-107 dBW/m2

MSITE™: TACOMA 800MHZ - CONTOURS

Aggregate power flux density
🟩 = -107.0 dBW/m2
Display threshold level: -120.0 dBmW
RX Antenna - Type: OMNI
Height: 1.0 m AGL Gain: -10.30 dBd

Sites

Site: Fire_Training
N47°15'11.00" W122°23'58.00" 7.0 m
FireTrai Tx.Ht.AGL: 18.1 m Total ERPd: 20.00 dBW
Model: 1 directional-horizontal/0.0° 851.0000 MHz

Site: Graham_Hill
N47°01'45.13" W122°18'01.45" 281.1 m
GrahamHi Tx.Ht.AGL: 54.1 m Total ERPd: 20.00 dBW
Model: 1 directional-horizontal/0.0° 862.0000 MHz

Site: Indian_Hill
N47°18'15.00" W122°24'44.00" 165.8 m
IndianHL Tx.Ht.AGL: 18.1 m Total ERPd: 20.00 dBW
Model: 1 directional-horizontal/0.0° 851.0000 MHz

Site: LESA
N47°13'43.00" W122°28'01.00" 107.8 m
LESA Tx.Ht.AGL: 30.3 m Total ERPd: 20.00 dBW
Model: 1 directional-horizontal/0.0° 851.0000 MHz

Site: Pearl_St
N47°16'13.78" W122°31'01.12" 121.6 m
PearlSt Tx.Ht.AGL: 18.1 m Total ERPd: 20.00 dBW
Model: 1 directional-horizontal/0.0° 851.0000 MHz

Terrain elevations
☐ Shaded relief illumination color

SPARLING

Contours
B15892 2/10/2010

BDA Interference

- What is a BDA? ….. Bi-Directional Amplifier

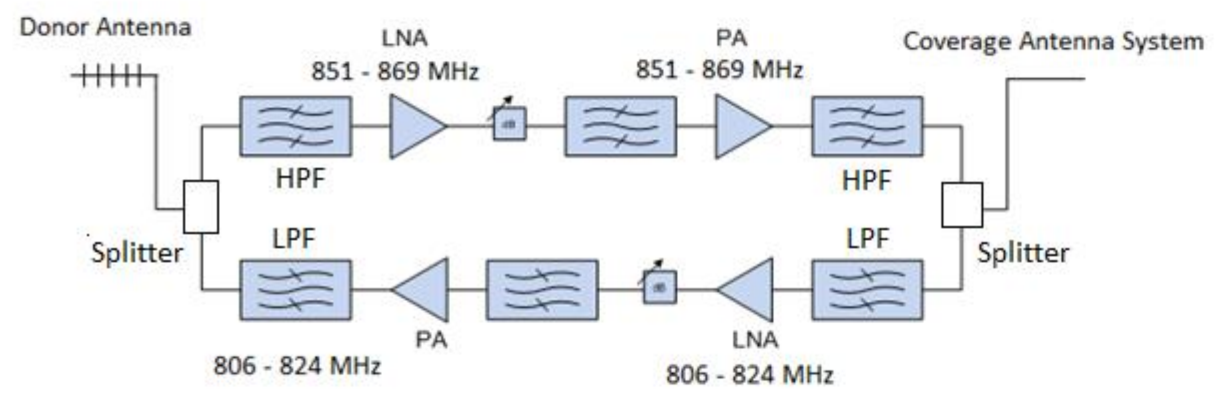
  - FCC designated as a “Signal Booster”, a dual repeater that simultaneously amplifies uplink (internal to external) and downlink (external to internal) signals while providing isolation between both sides

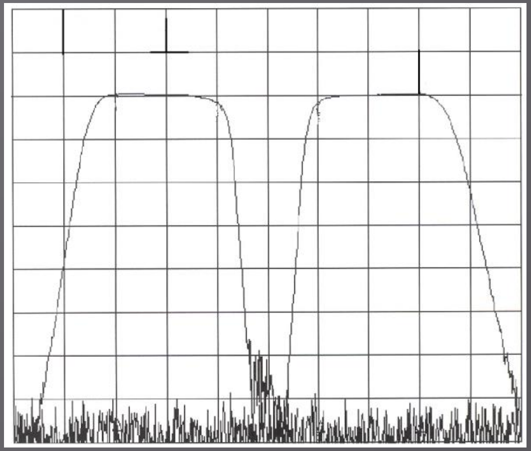
  - Used to extend signal coverage inside of buildings, now a National IBC/IFC Code requirements for in-building Public Safety First Responder Radio Systems

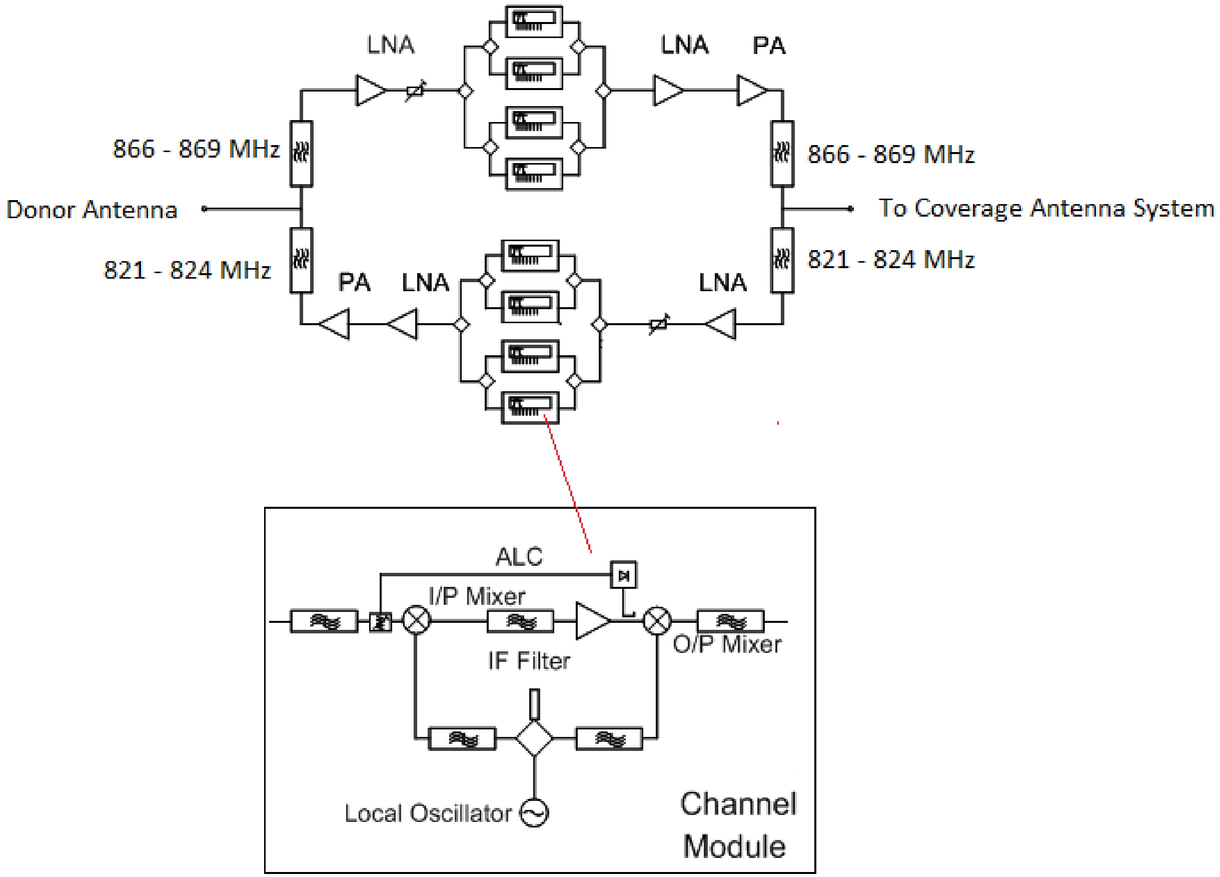
The $15,000 BDA

The $225 BDA

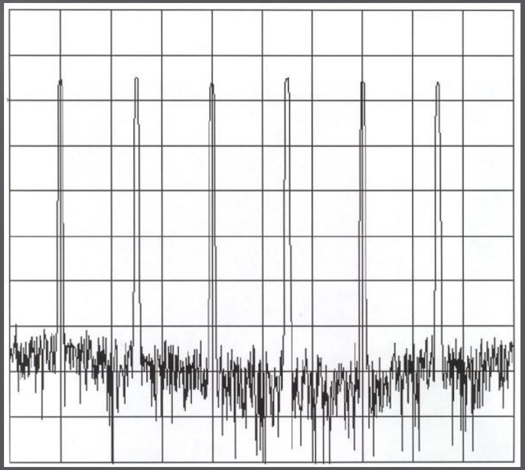
Wilson Electronics
CELL PHONE SIGNAL BOOSTER
New & Improved Performance
Simple Installation
20 TIMES
SIGNALBOOST DT DESKTOP







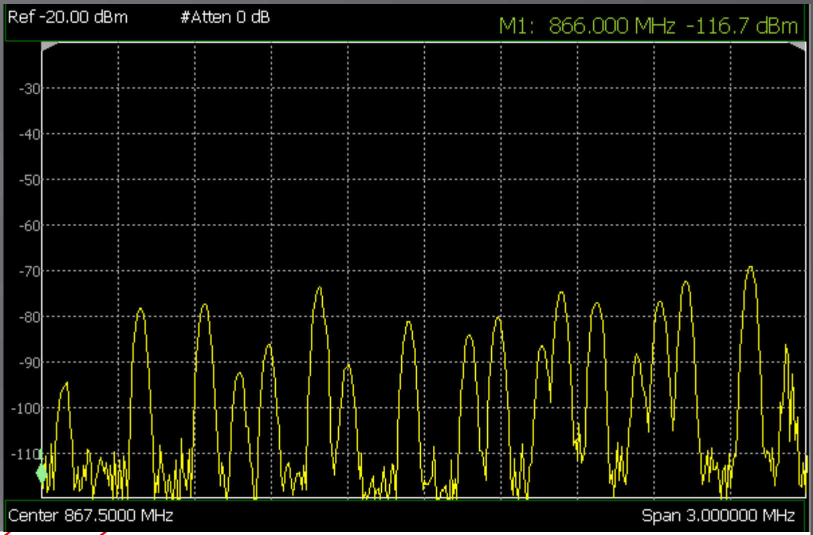
- Two main types:
  Type A – Channelized
  Type B – Band Pass
- Typ. 5 – 20 W output

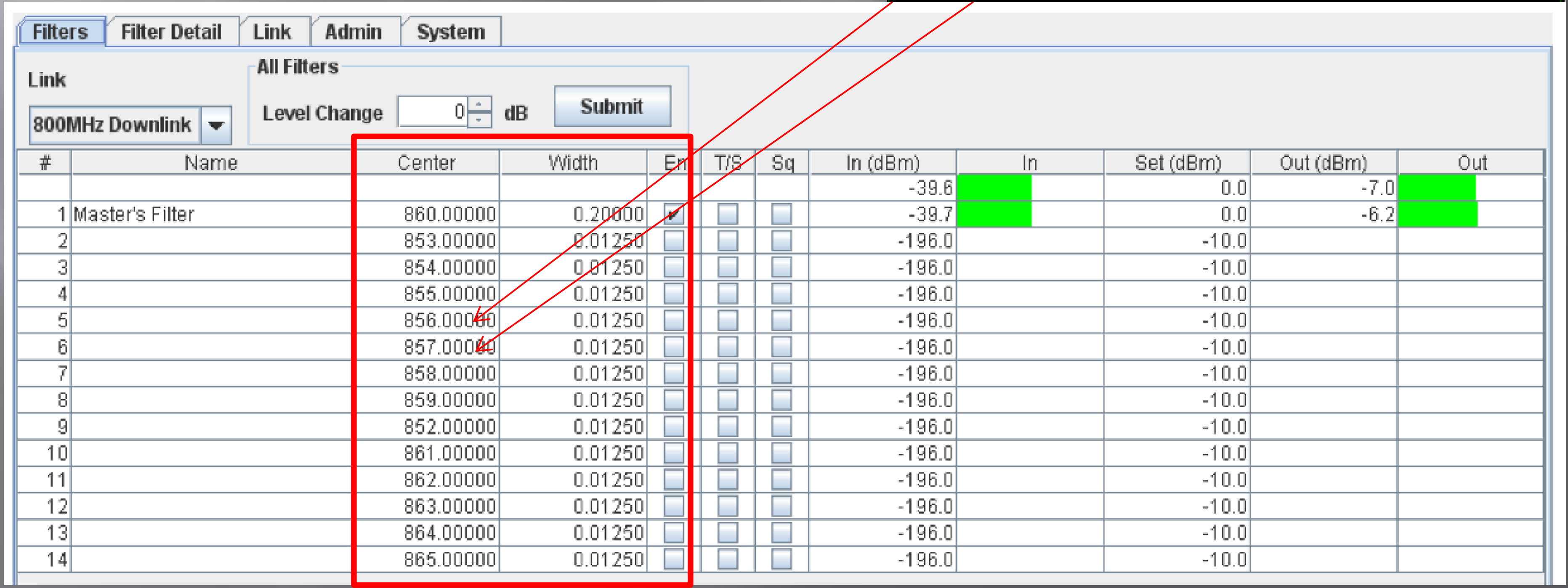


Bi-Directional Amplifier

Channelized DAS

- DSP filter individually tailored





Link: 800MHz Downlink

All Filters

Level Change: 0 dB

#	Name	Center	Width	En	T/S	Sq	In (dBm)	In	Set (dBm)	Out (dBm)	Out
							-39.6	🟩	0.0	-7.0	🟩
1	Master's Filter	860.00000	0.20000	☑	☐	☐	-39.7	🟩	0.0	-6.2	🟩
2		853.00000	0.01250	☐	☐	☐	-196.0		-10.0		
3		854.00000	0.01250	☐	☐	☐	-196.0		-10.0		
4		855.00000	0.01250	☐	☐	☐	-196.0		-10.0		
5		856.00000	0.01250	☐	☐	☐	-196.0		-10.0		
6		857.00000	0.01250	☐	☐	☐	-196.0		-10.0		
7		858.00000	0.01250	☐	☐	☐	-196.0		-10.0		
8		859.00000	0.01250	☐	☐	☐	-196.0		-10.0		
9		852.00000	0.01250	☐	☐	☐	-196.0		-10.0		
10		861.00000	0.01250	☐	☐	☐	-196.0		-10.0		
11		862.00000	0.01250	☐	☐	☐	-196.0		-10.0		
12		863.00000	0.01250	☐	☐	☐	-196.0		-10.0		
13		864.00000	0.01250	☐	☐	☐	-196.0		-10.0		
14		865.00000	0.01250	☐	☐	☐	-196.0		-10.0		

Bi-Directional Amplifier

- Need to be professionally engineered and installed
- Some are available online and in truck stops
- Without proper gain adjustment and uplink/downlink isolation, oscillation/feedback can occur.
- Harmonics IMD products
- Spurious energy raises the ambient RF noise level and can adversely affect repeater input sensitivity

Elevated RF Noise Floor

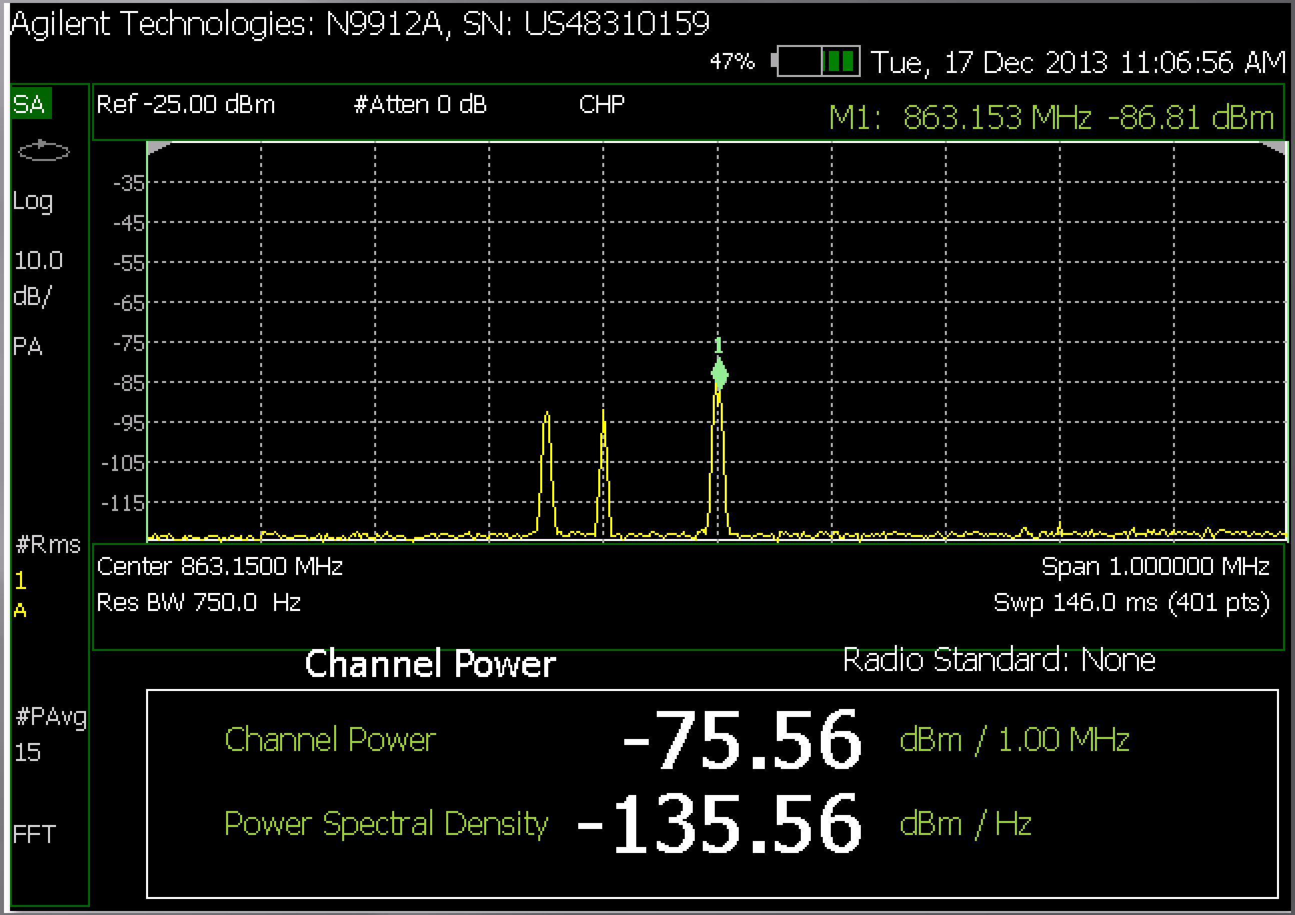
- Ambient energy present on a frequency due to natural and man-made sources
- Typically (ideally) range from -131 ~ -120 dBm
- This is the energy level that the receiver “sees” all the time
- As the noise floor energy increases due to IX, it competes with actual desired received signals

Elevated RF Noise Floor

- The higher the noise floor, the greater a signal's energy must be for the receiver to adequately detect and demodulate
- High noise floors:
  - makes a receiver more "deaf" (not does not affect sensitivity)
  - effectively reduces operating range
- Cellular carriers' nightmare

- reduce data access speed
- reduce battery life (dynamic power control)
- dropped calls

Off-Air Example of Ambient RF Noise Level



Agilent Technologies: N9912A, SN: US48310159

47% Tue, 17 Dec 2013 11:06:56 AM

Ref -25.00 dBm #Atten 0 dB CHP

M1: 863.153 MHz -86.81 dBm

10.0 dB/

Center 863.1500 MHz

Res BW 750.0 Hz

Span 1.000000 MHz

Swp 146.0 ms (401 pts)

#PAvg 15

Channel Power

Radio Standard: None

Channel Power -75.56 dBm / 1.00 MHz

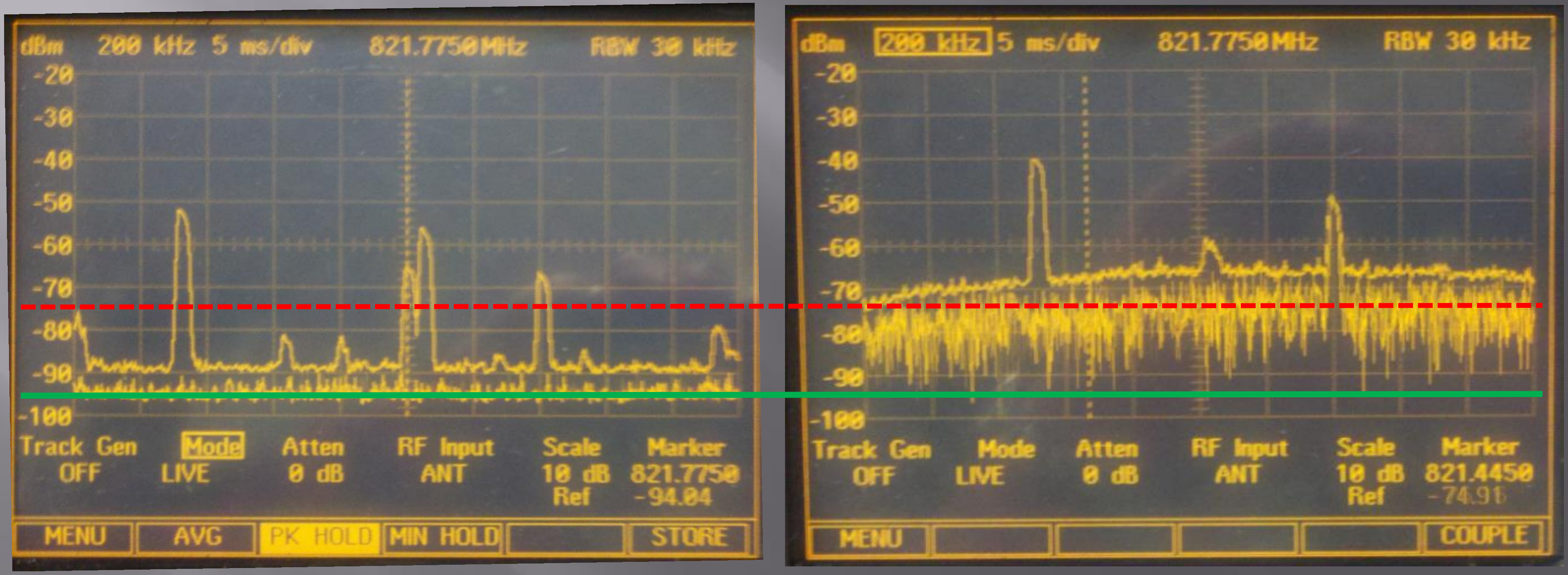
Power Spectral Density -135.56 dBm / Hz

BDA Induced IX Case

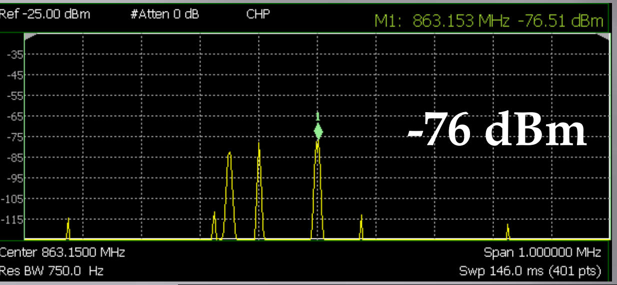
- **800 MHz PS Base Station RX Input (uplink)**

BDA OFF

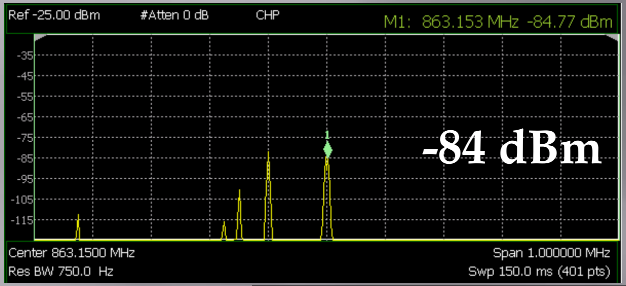
BDA ON



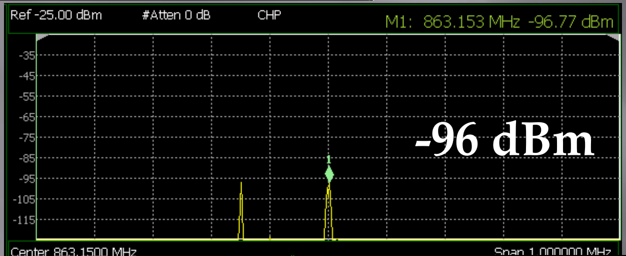
BDA/DAS Desense IX Case


Ref -25.00 dBm #Atten 0 dB CHP
M1: 863.153 MHz -76.51 dBm
Center 863.1500 MHz Span 1.000000 MHz
Res BW 750.0 Hz Swp 146.0 ms (401 pts)

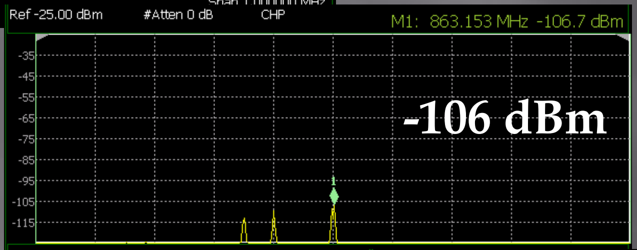
-76 dBm


Ref -25.00 dBm #Atten 0 dB CHP
M1: 863.153 MHz -84.77 dBm
Center 863.1500 MHz Span 1.000000 MHz
Res BW 750.0 Hz Swp 150.0 ms (401 pts)

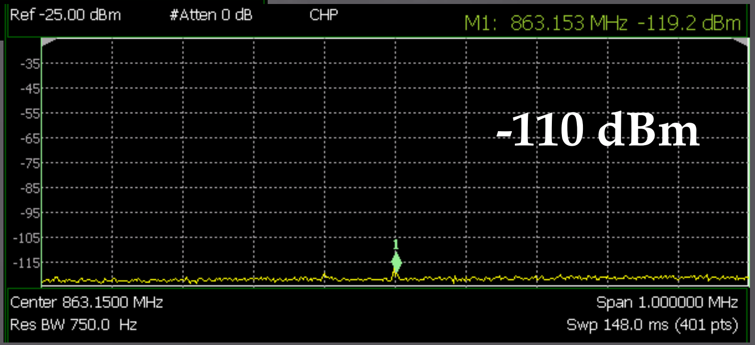
-84 dBm


Ref -25.00 dBm #Atten 0 dB CHP
M1: 863.153 MHz -96.77 dBm
Center 863.1500 MHz Span 1.000000 MHz
Res BW 750.0 Hz

-96 dBm


Ref -25.00 dBm #Atten 0 dB CHP
M1: 863.153 MHz -106.7 dBm
Center 863.1500 MHz
Res BW 750.0 Hz

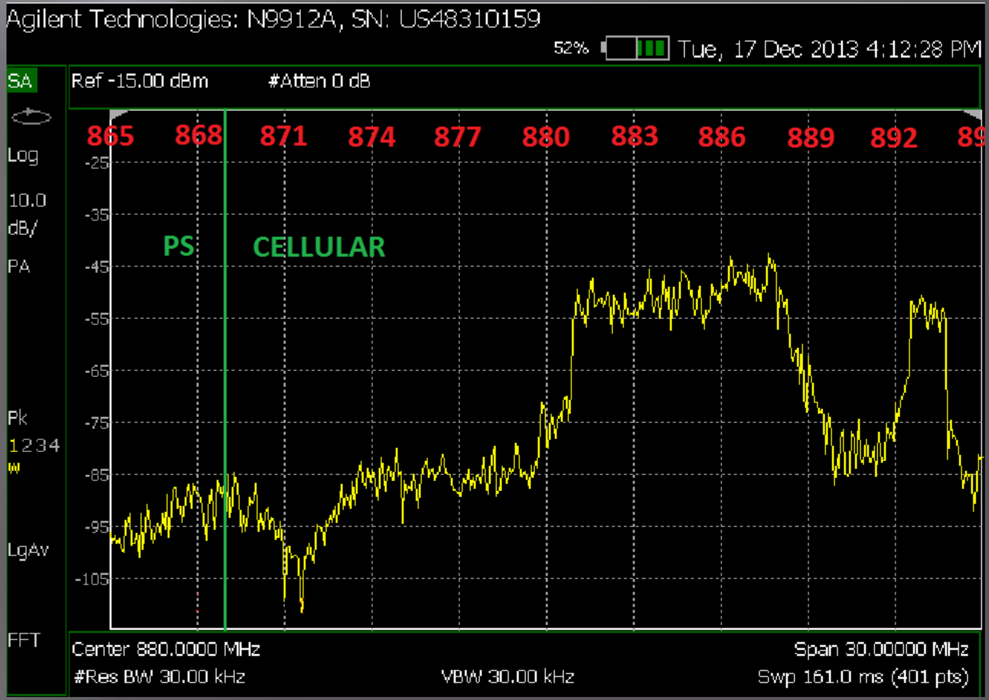
-106 dBm


Ref -25.00 dBm #Atten 0 dB CHP
M1: 863.153 MHz -119.2 dBm
Center 863.1500 MHz Span 1.000000 MHz
Res BW 750.0 Hz Swp 148.0 ms (401 pts)

-110 dBm

BDA Desense from Cellular IX Case

Cellular Block A and 800 PS NPSPC adjacent (with 1 MHz guard)



Agilent Technologies: N9912A, SN: US48310159

52% Tue, 17 Dec 2013 4:12:28 PM

Ref -15.00 dBm #Atten 0 dB

Center 880.0000 MHz Span 30.00000 MHz

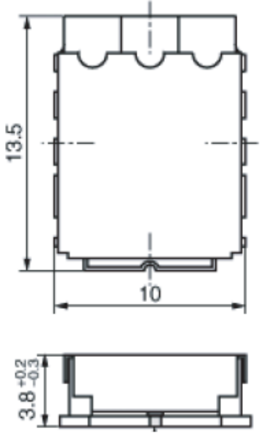
#Res BW 30.00 kHz VBW 30.00 kHz Swp 161.0 ms (401 pts)

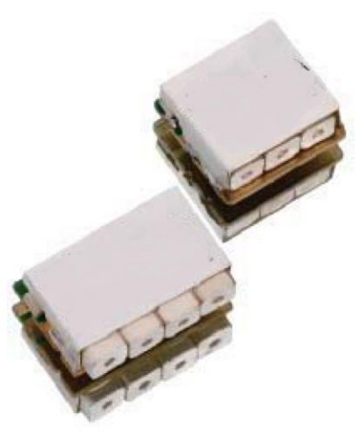
SPARLING

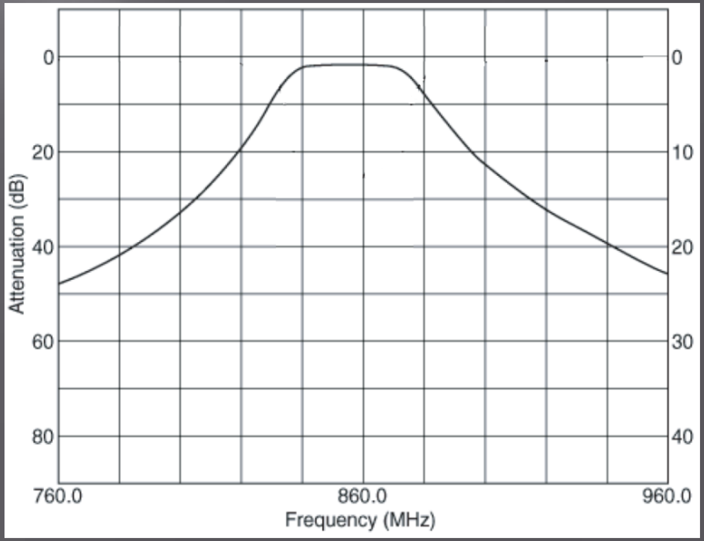
Why Radios Experience IX

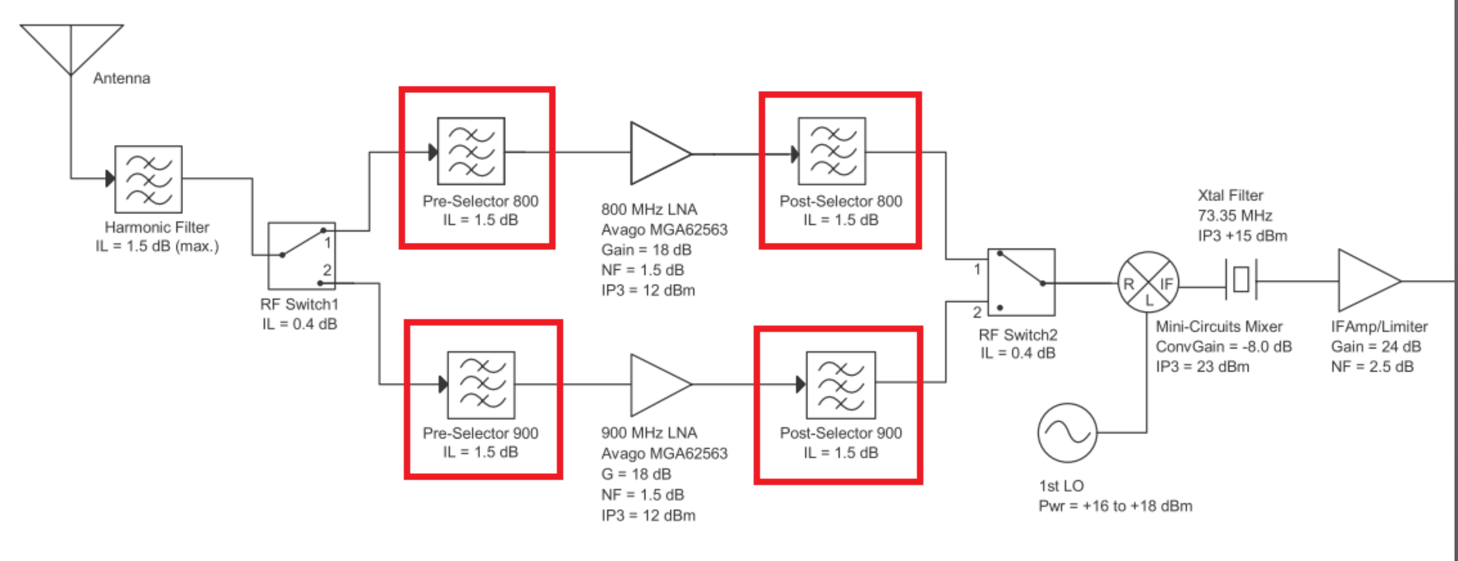
Radio Performance

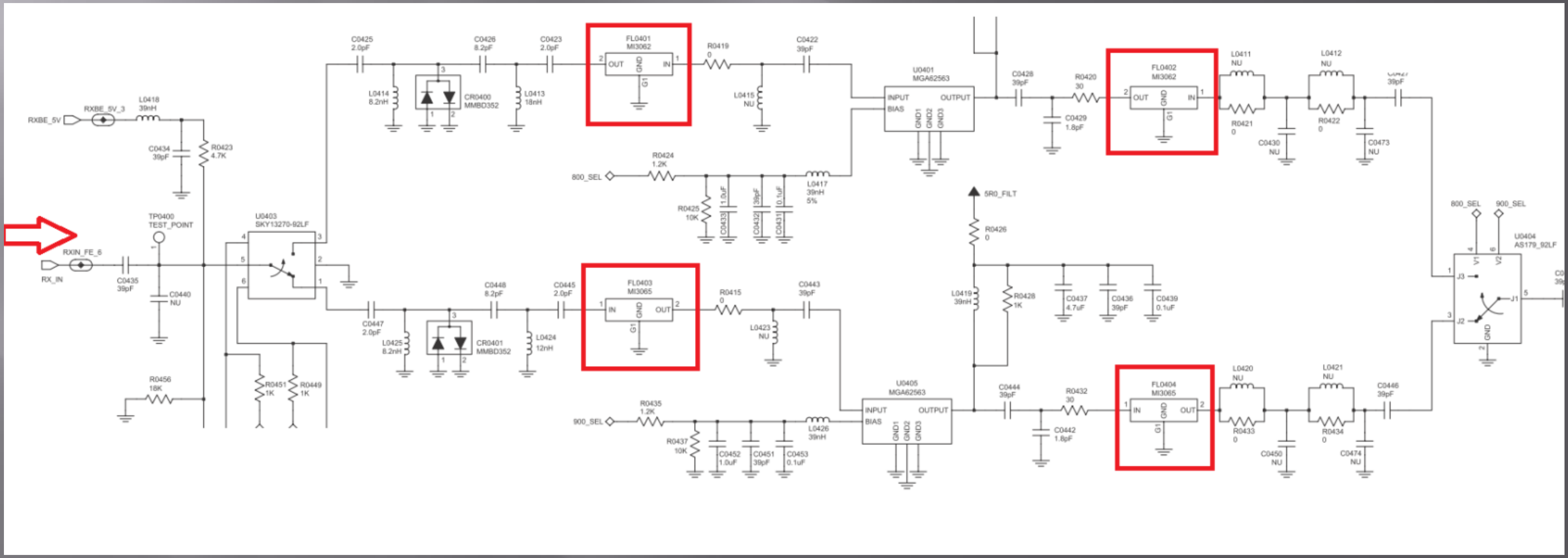
- Modern radios design for frequency agility over wide range
  - Ex. UHF 67 MHz BW (403 – 470 MHz)
  - Ex. 800 MHz 18 MHz (851 – 869 MHz)
- Ceramic Pre-Tuned Filter vs. helical "old school" preselectors
- Size and weight vs. performance compromise
- Nobody wants a bulky portable radio

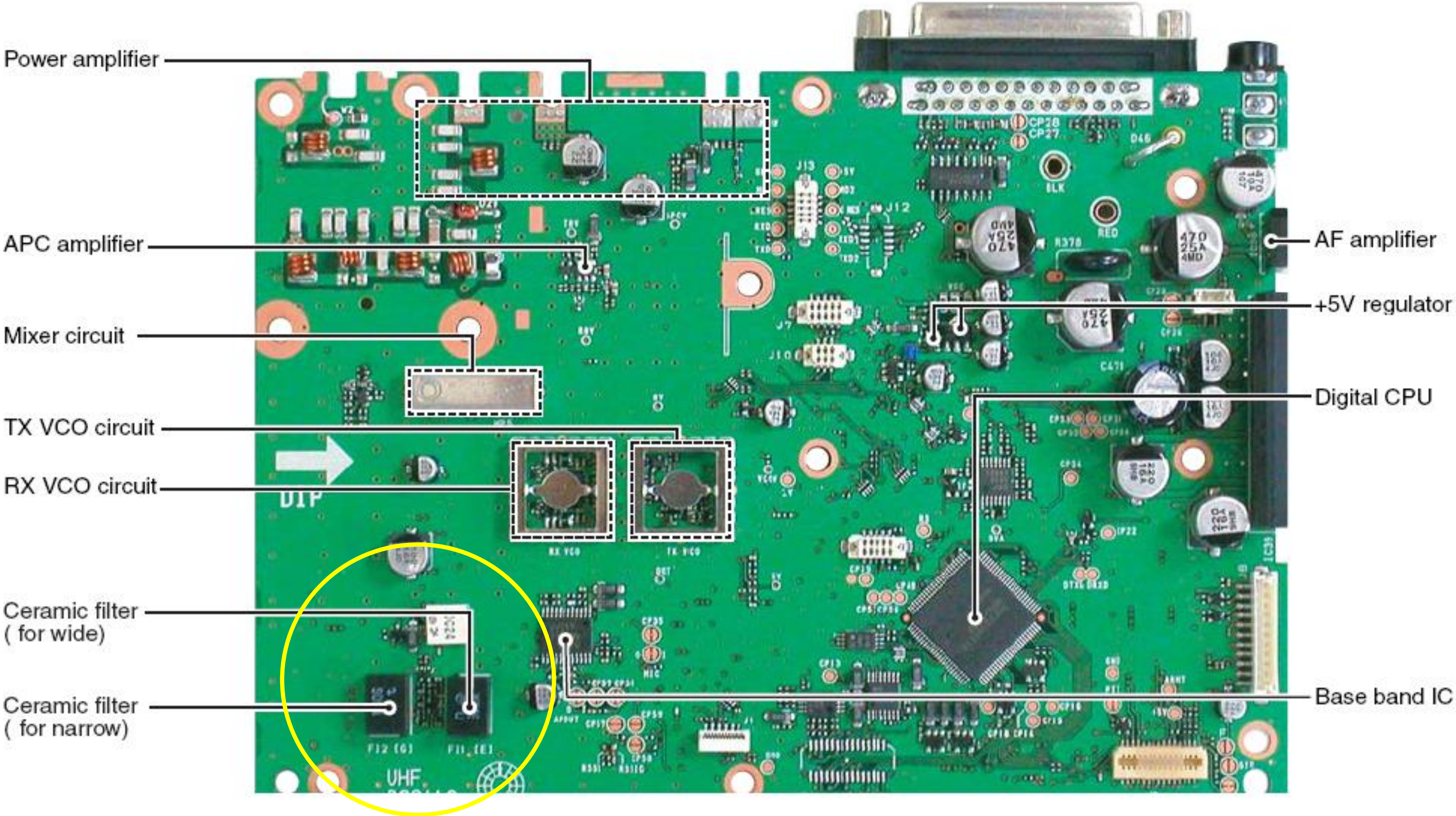







Antenna
Harmonic Filter
IL = 1.5 dB (max.)
RF Switch1
IL = 0.4 dB
1
2
Pre-Selector 800
IL = 1.5 dB
800 MHz LNA
Avago MGA62563
Gain = 18 dB
NF = 1.5 dB
IP3 = 12 dBm
Post-Selector 800
IL = 1.5 dB
Pre-Selector 900
IL = 1.5 dB
900 MHz LNA
Avago MGA62563
G = 18 dB
NF = 1.5 dB
IP3 = 12 dBm
Post-Selector 900
IL = 1.5 dB
RF Switch2
IL = 0.4 dB
R
IF
L
Mini-Circuits Mixer
ConvGain = -8.0 dB
IP3 = 23 dBm
Xtal Filter
73.35 MHz
IP3 +15 dBm
IFAmp/Limiter
Gain = 24 dB
NF = 2.5 dB
1st LO
Pwr = +16 to +18 dBm


RXBE_5V
RXBE_5V_3
L0418
39nH
C0434
39pF
R0423
4.7K
TP0400
TEST_POINT
RXIN_FE_6
RX_IN
C0435
39pF
C0440
NU
R0456
18K
U0403
SKY13270-92LF
R0451
1K
R0449
1K
C0425
2.0pF
L0414
8.2nH
CR0400
MMBD352
C0426
8.2pF
L0413
18nH
C0423
2.0pF
FL0401
MI3062
OUT
IN
GND
G1
R0419
0
L0415
NU
C0422
39pF
U0401
MGA62563
INPUT
OUTPUT
BIAS
GND1
GND2
GND3
800_SEL
R0424
1.2K
R0425
10K
C0433
1.0uF
C0432
39pF
C0431
0.1uF
L0417
39nH
5%
C0428
39pF
R0420
30
C0429
1.8pF
FL0402
MI3062
L0411
NU
R0421
0
C0430
NU
L0412
NU
R0422
0
C0473
NU
C0427
39pF
5R0_FILT
R0426
0
L0419
39nH
R0428
1K
C0437
4.7uF
C0436
39pF
C0439
0.1uF
800_SEL
900_SEL
U0404
AS179_92LF
J1
J2
J3
V1
V2
GND
C0447
2.0pF
L0425
8.2nH
CR0401
MMBD352
C0448
8.2pF
L0424
12nH
C0445
2.0pF
FL0403
MI3065
R0415
0
L0423
NU
C0443
39pF
900_SEL
R0435
1.2K
R0437
10K
C0452
1.0uF
C0451
39pF
C0453
0.1uF
L0426
39nH
U0405
MGA62563
C0444
39pF
C0442
1.8pF
R0432
30
FL0404
MI3065
L0420
NU
R0433
0
C0450
NU
L0421
NU
R0434
0
C0474
NU
C0446
39pF


Power amplifier
APC amplifier
Mixer circuit
TX VCO circuit
RX VCO circuit
Ceramic filter
(for wide)
Ceramic filter
(for narrow)
AF amplifier
+5V regulator
Digital CPU
Base band IC

Passive Inter-Modulation (PIM)

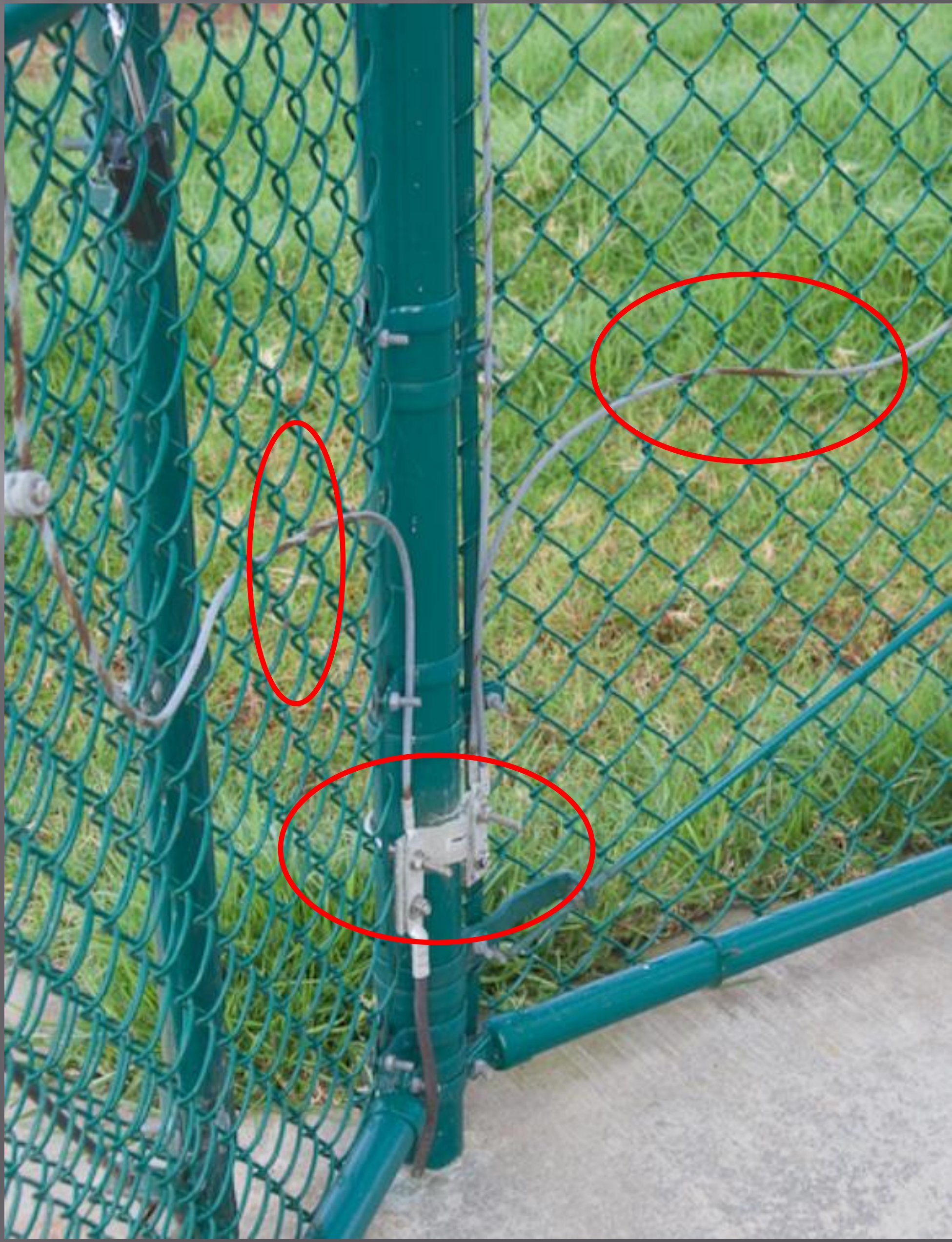
Origin (also known as “diode” or “rusty bolt” effect)

- Occurs when two or more signals present in a passive non-linear device or element mix or multiply with each other to generate other signals that are related to the first
- Nonlinearity caused by:
  - dissimilar metals (especially ferromagnetic: Fe Ni, steel alloys)
  - dirty interconnects
  - anodic effects
  - loose connections
  - transmitters sharing antenna runs
  - transmitters using adjacent antennas
  - nearby towers with conflicting antenna patterns
  - damaged or poorly torqued RF connections
  - contamination
  - fatigue breaks, cold solder joints
  - corrosion

SPARLING

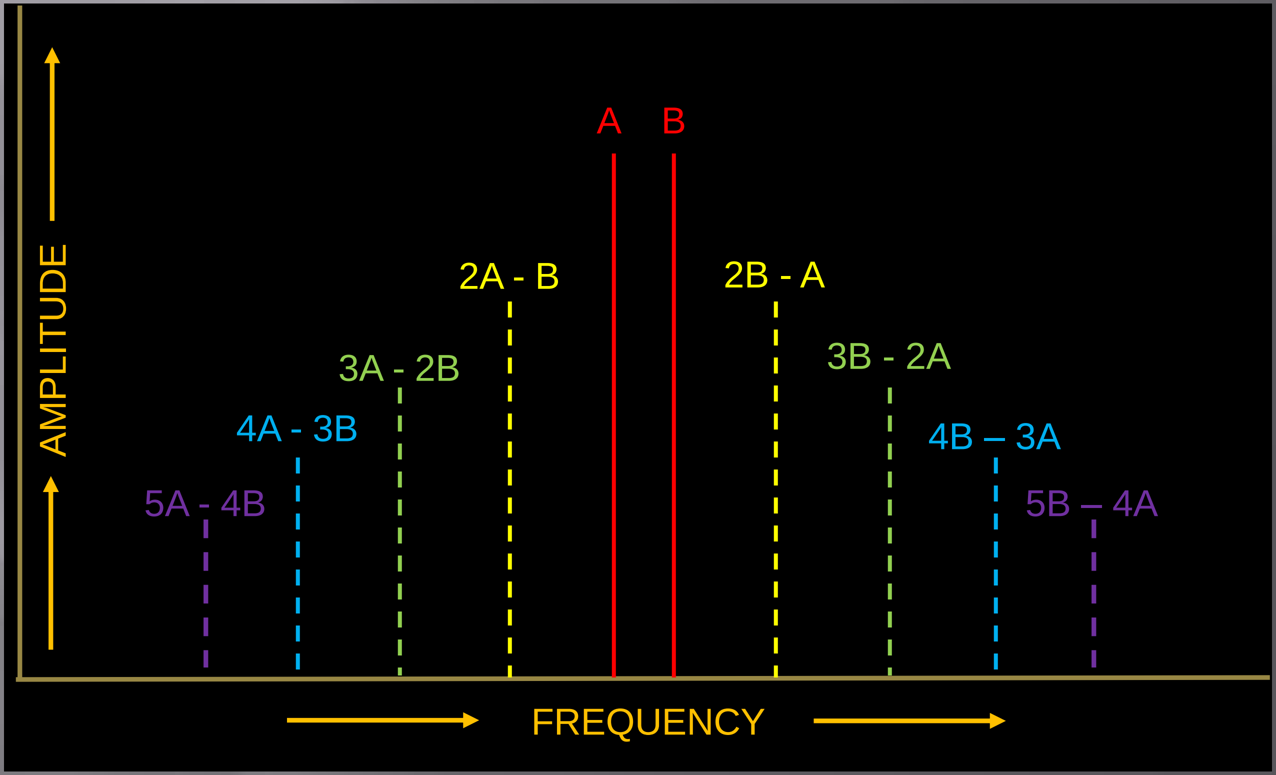
Passive Inter-Modulation (PIM)

Any problems is this grounded cyclone fence ?



Passive Inter-Modulation (PIM)

- Mathematical relationship of fundamental are *n*-th order harmonic generation



PIM Examples

FREQ. A = 851.250 **FREQ. B = 871.000**

3 x 851.250 (2553.75) – 2 x 871 (1742) = 811.750 MHz

3 x 871(2613) – 2 x 851.250 (1702.500) = 911.500 MHz

806 MHz – 815 MHz is the PS Uplink range

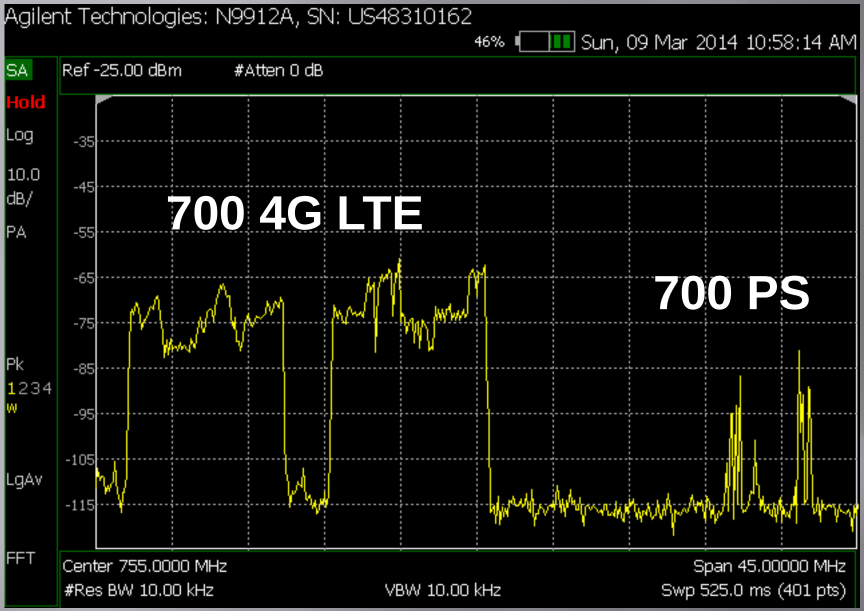
In this PIM case the intermodulation product can affect the repeater input.

Passive Inter-Modulation (PIM)

- More noticeable at **higher signal levels** either because not enough stress is placed on the dielectric or the PIM levels are at thermal noise level.
- Wide band signals create greater ranges of IM products than NB
- Faulty component acts as a mixer (ex. local oscillator and RF input)
- If generated PIM falls on direct or adjacent receiver channel, desensitization will occur.
- Often a mode of "self-interference"
- Can be constant or intermittent (ex. multi-channel trunking systems)
- More complex with wide-band carrier signals

Passive Inter-Modulation (PIM)

- Why is this a problem for Public Safety Radio System consideration?
  - Nationwide rollout of 4G 700 MHz and 850 MHz cellular data networks
  - More sites, more energy near PS sites
  - Real estate for site development increases in cost, more co-locations
  - Older sites lose grounding quality due to time, corrosion, and neglect
  - It doesn't have to be your site !


Agilent Technologies: N9912A, SN: US48310162

46% Sun, 09 Mar 2014 10:58:14 AM

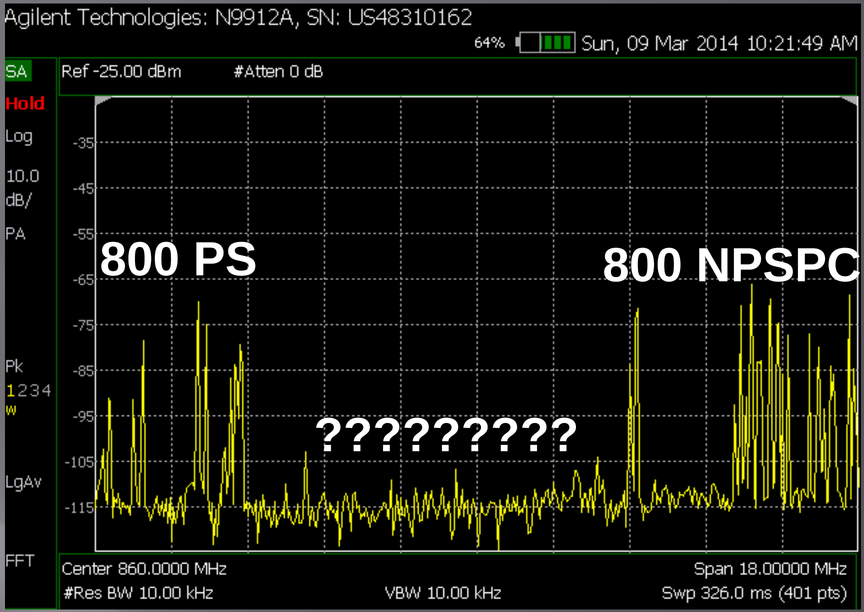
Ref -25.00 dBm #Atten 0 dB

Center 755.0000 MHz Span 45.00000 MHz

#Res BW 10.00 kHz VBW 10.00 kHz Swp 525.0 ms (401 pts)

700 4G LTE

700 PS


Agilent Technologies: N9912A, SN: US48310162

64% Sun, 09 Mar 2014 10:21:49 AM

Ref -25.00 dBm #Atten 0 dB

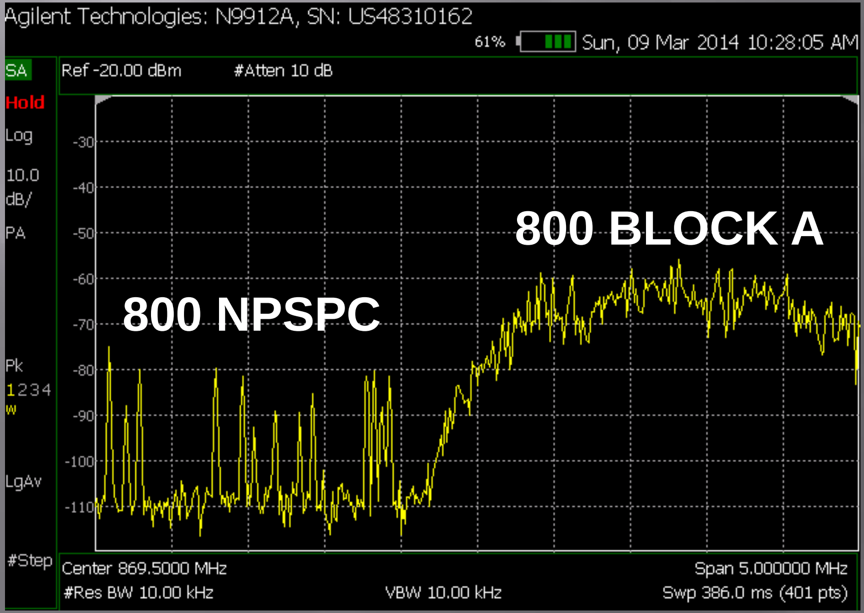
Center 860.0000 MHz Span 18.00000 MHz

#Res BW 10.00 kHz VBW 10.00 kHz Swp 326.0 ms (401 pts)

800 PS

800 NPSPC

?????????


Agilent Technologies: N9912A, SN: US48310162

61% Sun, 09 Mar 2014 10:28:05 AM

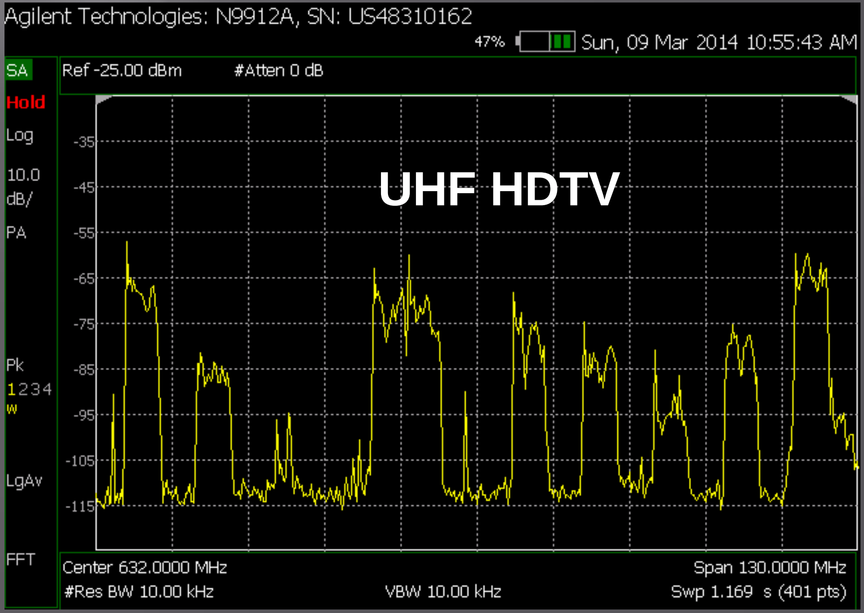
Ref -20.00 dBm #Atten 10 dB

Center 869.5000 MHz Span 5.000000 MHz

#Res BW 10.00 kHz VBW 10.00 kHz Swp 386.0 ms (401 pts)

800 BLOCK A

800 NPSPC


Agilent Technologies: N9912A, SN: US48310162

47% Sun, 09 Mar 2014 10:55:43 AM

Ref -25.00 dBm #Atten 0 dB

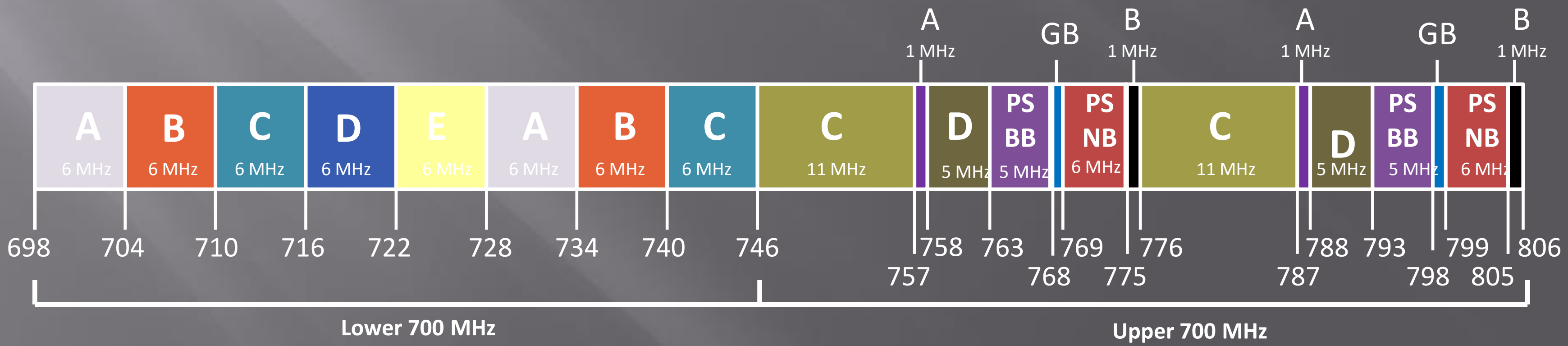
Center 632.0000 MHz Span 130.0000 MHz

#Res BW 10.00 kHz VBW 10.00 kHz Swp 1.169 s (401 pts)

UHF HDTV

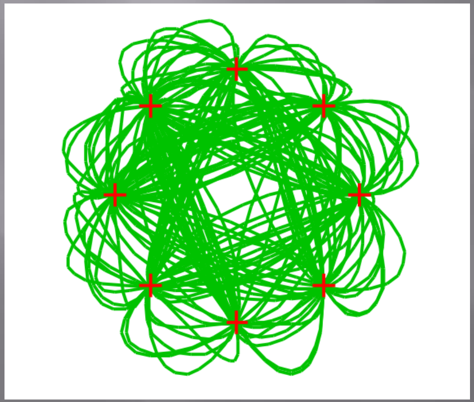
Passive Inter-Modulation (PIM)

- The 700 MHz bands is now being proliferated with PS 700 MHz P25 networks across the country
  - narrowband P25 TDMA voice channels
  - adjacent to LTE FirstNet™ National Public Safety Broadband Network
  - adjacent to multiple wireless carriers 4G LTE networks
- Déjà vu … ?



Passive Inter-Modulation (PIM)

- What about technology?
  - -Many PS radio systems migrating to P25 Phase 2 (TDMA)
  - - P25 Phase 2 modulation uses H-DQPSK – has an AM component and with multiple carriers can have a very high PIP (Peak Instantaneous Power)
- PIM training and resolution requires skill
- PIM testing equipment expensive



Passive Inter-Modulation (PIM)

How has the industry, cellular carriers and radio system owners responded to this interference issue?

- PIM rated site components
  - antennas
  - connectors 7/8" DIN
- New site designs start from scratch with PIM mitigation in components, grounding (R56) and testing.
- Higher qualifications on technicians and installers
  - PIM awareness
  - cable and connector preparation and installing
- PIM Testing using specialized equipment

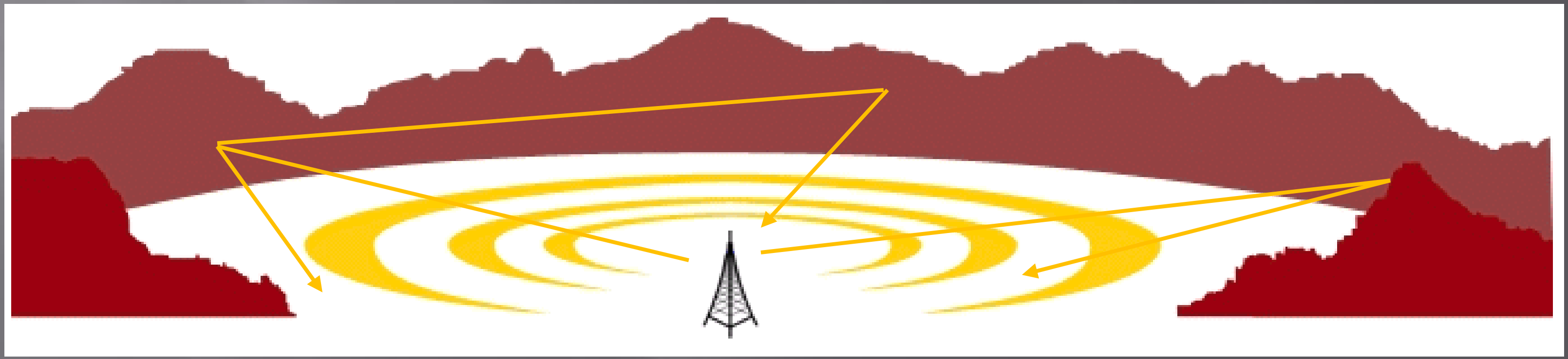
Body Plating - White Bronze
Contact Plating - White Bronze
Dielectric - PTFE
Coupling Nut - Stainless Steel

Multipath IX and P25

Radio signals often reach a receiver from multiple directions - from the incident transmission point and from reflected sources.

Puget Sound "fish bowl" and WA state topography is "perfect storm" for multipath distortion.

- mountains
- water
- buildings



Multipath IX and P25

Happens all the time but the "capture effect" of the discriminator in an FM receiver means you often don't notice this effect in a strong capture area.

At further distances from the TX source (i.e. weaker signal areas), the incident and reflect signal(s) can both be captured, but will be time shifted due to arrival delay and therefore phase shifted - resulting in audio distortion

- raspy audio
- general distortion
- popping noise

With the exception of extreme cases, levels of audio distortion can be randomly tolerated in problem areas.

Multipath IX and P25

So, what's the big deal? Digital Modulation is the big deal!

- PS radio systems transitioning to P25 nationwide
- LMR radio systems transitioning to DMR and NXDN
- Part 97 now have two mass-produced digital modes (D-Star and Vertex C4FM FDMA) as well as P25 and TRBO DMR-MARC/DCI

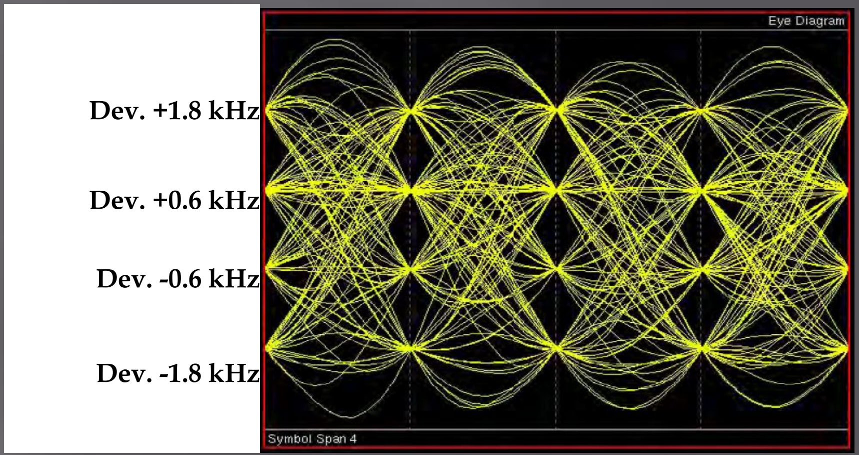
DMR
DIGITAL MOBILE RADIO ASSOCIATION
P25
DIGITAL WIRELESS · SANS FIL NUMÉRIQUE · INALÁMBRICO DIGITAL
iDAS
NEXEDGE
D-STAR

Multipath IX and P25

P25 uses digital modulation, which has a *completely different IX phenomena than analog!*

- **C4FM** – **C**onstant Envelope **4**-level FSK Modulation, 12.5 kHz, 9600 bps
- FSK of carrier to 4 deviation (symbol) points around a center frequency
- Each symbol state represent a binary number (DiBit/Symbol - 2 bits of information)

Information Bits	Symbol	C4FM Deviation
01	+3	+1.8 kHz
00	+1	+0.6 kHz
10	-1	-0.6 kHz
11	-3	-1.8 kHz



Multipath IX and P25

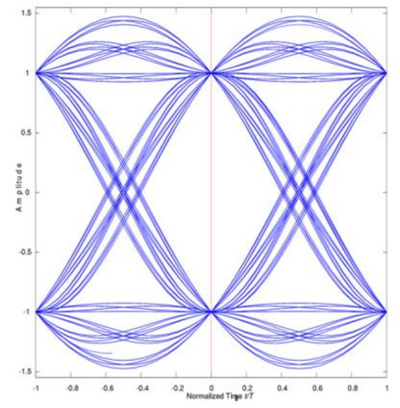
Phase distortion results in symbol interference

Symbol interference = Bit Error Rate (BER)

High BER = unrecoverable data

VOCODER response to high BER:

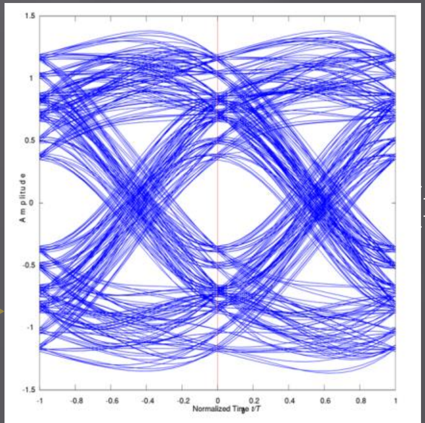
- Non-speech synthesis (“R2D2”)
- Partial muting*
- Silence* (*dependent upon digital squelch setting and BER%)



Ideal

C4FM Eye Diagram

Phase
Distortion



(multi-path)

Multipath IX and P25

Why is this a big problem…?

High BER synthesized non-speech is not only unintelligible, its annoying

- Analog degradation has classic S/N we all understand
  (signal decreases, noise increases)
- Digital degradation phenomenon highly variable
  (dependent upon radio manufacture, digital squelch setting and alignment of radio)

High BER resulting in muted speech segments may be harder for the human brain to recreate than analog = lost content

…….. shoot !

Don’t shoot !

Multipath IX and P25

Why is this a big problem…?

Silence/non-receive due to high BER means an operator may not realize they were being called = lost transmission

High BER may offer no clue as to its origins !

- uplink limited issue
  (noisy during transmission, quiet carrier during hang-time)
- downlink limited issue
  (noisy during transmission and hang time)
- multipath generated issue
  (classic distortion sounds, nulls and fades, varies with location)
- network connectivity issue
  (high BER, latency, jitter)
- subscriber radio alignment issue
  (analog frequency error of 1 kHz - 2 kHz in Part 97 FM still recoverable, digital frequency error of more than 400 -500 Hz can cause problems)

Multipath IX and P25

Off-Air recordings

- From my mobile amateur DMR radio (Motorola XPR5500)

- UHF MotoTRBO™ repeater (Cougar Mt.)

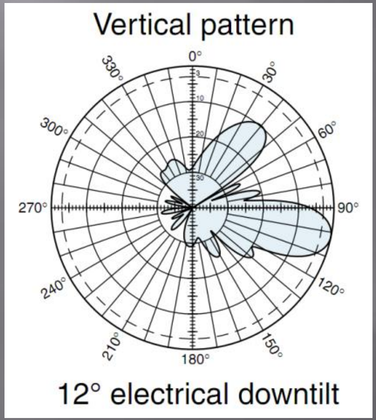
- DCI TRBO6 Amateur Network

- Other station in New York state

Multipath IX and P25

What can be done to improve performance ?

- Radio system design and engineering
  - **Simulcast Transmission** – "managed multipath"
  - **Voted receive** – in digital system this is BER voting, in some cases multiple data streams are aggregated and error corrected
  - **Diversity receive** – dual antennas on one receiver correlating input signals
  - **Down-tilt antennas** (mechanical and electrical) 3° ~ 15°
  - transceiver and repeater testing and alignment (automated test of TX BER and Mod Fidelity, 5% max acceptable BER)
- User training, understanding the world of digital voice



Vertical pattern

12° electrical downtilt

The END

QUESTIONS ?